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Site-Specific Wood Residue Assessments and Their Implications for Greater Resource Recovery

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SITE-SPECIFIC WOOD RESIDUE ASSESSMENTS AND THEIR IMPLICATIONS FOR GREATER RESOURCE RECOVERY

EXECUTIVE SUMMARY

Four local wood residue assessments, funded under the Energy Security Act, were conducted to determine the feasibility of expanding the use of wood residues for energy. The studies were conducted under the direction of Forest Service scientists in the following regions: Northern New England, Piedmont South Carolina, Northeastern Minnesota, and Northwestern Montana

The significant findings are summarized here.

Northern New England

* In the two timbersheds studied, the raw material supply was adequate. Annual removals for all uses in the Burlington Electric and S. D. Warren timbersheds could be increased by a factor of four, and a factor of three, respectively.

* In Maine, New Hampshire, and Vermont, there are 250 manufacturers or institutions and businesses that use wood to furnish part or all of their energy needs. Between 1982 and 1992, woodfuel consumption is expected to increase by 75 percent. Large non-forest products manufacturers that now only account for 3 percent of the region's industrial energy consumption are expected to expand rapidly and double their woodfuel consumption by 1992. Employment in the wood energy sector, that constitutes 35 percent of total energy employment, is expected to increase 39 percent by 1992.

* Currently 5.6 million cunits of forest residues are potentially available in the Burlington Electric timbershed at an average delivered cost of $32/cunit or $15.20 per green ton. In the S.D. Warren timbershed, about 5.5 million cunits are potentially available at an average cost of $28/cunit. Burlington Electric consumes 500,000 green tons or about 200,000 cunits per year.

* It is generally uneconomic to reenter areas after the harvest to remove logging residues, because of the small piece size and low per acre volume of residues.

* There are no cost differences between transporting roundtimber or wood chips.

* Transportation costs per ton-mile average 8.5 cents for truck transport and 5 cents for interstate rail shipments, however, since 1978, trucking costs for woodfuel have risen 70 percent.

* Northern New England can accommodate several additional wood-fired electric generating plants (50-MW range) without affecting other wood using industries.

* Currently the factor which limits the use of wood residues for energy is their cost in relation to the cost of hydropower from Canada.

Southern Piedmont Region

* Current residue types, volumes, and roadside costs in the study area are:

Residue Type	MM Green tons available annually	Dollars/ton delivered
Forest residues and noncommercial stands	6.770	27
Land conversion	.255	18
Salvage	.919	18
Primary mill residues	1.020	12

* Potential demand estimates ranged from 0.6 to 3 million green tons in the intermediate term with the most likely level approaching 1.5 million green tons per year.

* The primary barrier to wood energy development is judged to be a limited awareness and acceptance among industrial firms, utilities, and state and local bodies.

* Woodfuel development is estimated to have little effect on other industrial wood except, perhaps, for a simultaneous decrease in price and increase in quality of saw logs.

* Wood residue energy development should be generally feasible in the area and in fact would support electric generating plants (50-MW range) at favorable prices.

* Two factors limit the use of wood residues for energy; (1) wood residues are approximately equal in cost to coal (an alternate fuel), and (2) there is a limited awareness and acceptance of wood as an energy source among industrial firms, utilities, state and local governments, and the general public in the region.

Northeastern Minnesota

* NE Minnesota's forest resource could supply significantly more wood to an energy market without causing large cost increases to other forest products. In the long run, the increased fuelwood market could lower wood costs.

* Many existing barriers to increased energy development can be removed at low cost by modifying current attitudes and policies that govern forest management. Wood energy is a valid use, in no way inferior to sawtimber or pulpwood. Policies can be developed to allow wood energy, or any other use, to compete on its own merits.

* Increased harvesting during the next 10-20 years would enhance future forest productivity; older, slower growing, understocked stands would be replaced with young, fast growing, fully stocked stands.

* Using more of this wood for local and regional energy needs will reduce regional energy costs, increase regional output, and increase regional employment; all of which are critical problems in NE Minnesota.

Northwestern Montana

* At normal industrial production levels, about 100,000 cunits of fine wood residues and bark are available annually in the study area for fuel. Delivered costs range from $10 to $30 per cunit.

* Forest residues could contribute another 120,000 to 200,000 cunits of woodfuel annually. Delivered cost of about $45 per cunit includes woods extraction, chipping, and transportation.

* The generation of electricity from wood in the Libby area would only be feasible with very low wood and capital costs. High cost forest residues for electric generation would be practical only if very large increases in electrical buyback rates were achieved to partially offset wood costs. The use of wood as a substitute fuel for oil or natural gas may be practical if the system has low capital costs and a high degree of capacity utilization. Under these conditions wood costs of up to $70 per cunit could be borne. Systems with high capital costs or low capacity utilization might not be feasible even if the wood is free.

* The use of forest residues as a substitute fuel for coal is unlikely because wood costs more than coal.

* The major barriers to increased wood residue use in the Inland Northwest are economic. In addition, a number of other factors, such as complex permitting and siting regulations, and land management and environmental concerns must be addressed. State and Federal agencies in the region are actively involved in programs to eliminate unnecessary constraints.

I. INTRODUCTION

BACKGROUND

Energy from the conversion of wood residues[1/] represents an important untapped resource in the United States. The amount of energy supplied by biomass (mostly wood residues) is now relatively small; 2.7 Quads of a total of 74 Quads currently used.

Residue use could expand rapidly in the next two decades, however, and according to a Congressional report (OTA, 1980) provide up to 10 Quads annually by the year 2000. This would represent about 10 percent of total use. The increase in use would depend on a variety of factors, including physical and economic availability of wood residues, adequate market alternatives, proper resource management, level of policy support in removing barriers to use, and costs relative to alternative energy sources.

The GAO report "The Nation's Unused Wood Offers Vast Potential Energy and Product Benefits" (GAO, 1981) stated that there is a need to place higher priority on encouraging the use of wood residues as an energy source and on wood products as a substitute for more energy-intensive materials in manufacturing.

Despite their recognized potential, immense quantities of wood residues--decaying logging residues and dead trees, unused wood-processing residues and vast, untapped acreages of small, defective, and other lower value trees are wasted each year. This report recommends that local assessments be undertaken which could develop such specific information as: volumes and cost of residues available for energy, barriers to residue utilization, and the appropriate Federal role in developing biomass energy.

In line with the GAO recommendations and in order to quantify the amount of wood residue that might be available for use and to provide policy makers with a basis for encouraging greater wood recovery and substitution of wastewood for expensive energy, the U.S. Department of Agriculture's Office of Energy and the Forest Service conducted four local

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1/ Wood residues, as defined for purposes of assessment, include all wood and bark material that remains unused following timber removal or primary manufacture. Forest residues include the unused portions of harvested trees, salvable standing and down dead stems on harvested or cleared sites, and live trees passed over during harvesting operations because of poor quality, excessive rot, size limitations, or inadequate demand.

assessments that are representative of the best residue utilization opportunities within their respective regions; and in the aggregate, within the entire Nation. The work was funded with Energy Security Act funds.

The objective of these local assessments was to evaluate wood residue utilization opportunities on a local or site specific basis.

SELECTING ASSESSMENT AREAS

Wide variations exist in residue character, quantity, availability, and utilization potential between regions of the United States. Useful evaluation of residue recovery potential depended on development of site-specific assessments for well defined operating areas. Some of the criteria used in selecting assessment areas included:

1. an apparent high potential for economically feasible residue recovery. Evidence includes relatively large residue volume generations; favorable location, accessibility, and transportation factors; and energy costs encouraging the development of alternative sources;

2. existence of a viable forest products industry within the area. Diversified forest products firms with relatively high energy needs and the capability to develop centralized energy generation facilities may offer the best opportunities;

3. areas representative of a major productive timber type within the region. Long-term continuity of supply will depend upon a sustained level of timber production and harvesting over time. One-time events--insect epidemics, land clearing, type conversion, etc.--may afford large volumes of residues at a single point in time, but cannot sustain a continuing industrial operation;

4. existing interest in the use of wood for fuel and fuel feedstocks by one or more major facilities.

In addition, a number of secondary criteria were also considered including:

1. the ready availability of existing data bases, resource expertise, and other sources of information and assistance relevant to conducting an assessment;

2. the absence of sources of assured supply, low-cost energy. Low cost alone may not be an adequate basis for evaluating the need for alternative energy sources; uncertain or interruptable energy supply may be an even more critical issue for industry in the area;

3. presence of a favorable institutional and political climate for the development of alternate energy sources;

4. absence of major constraints on direct combustion.

Based upon the above criteria, research proposals from throughout the United States were reviewed. Proposals from the following four regions were selected.

REGION	CONTACT
1. Northern New England	Paul E. Sendak, Northeastern Forest Experiment Station, Burlington, Vermont.
2. Piedmont Region of South Carolina	H. Kenneth Cordell, (James W. McMinn) Southeastern Forest Experiment Station Athens, Georgia.
3. Northeastern Minnesota	Edwin Kallio, (Dennis Bradley) North Central Forest Experiment Station, Duluth, Minnesota.

4. Northwestern Montana	Roland L. Barger, Intermountain Forest & Range Experiment Station, Missoula, Montana.

INTERPRETING FINDINGS

The findings from the local wood residues assessments are summarized in the following chapters. Although the same topics were addressed in each assessment, the findings are not directly comparable, because different methodology was employed in different geographic regions. A crude ranking of economic opportunities might be possible, however, since the use of wood residues for energy will obviously prove to be more attractive in one study locality than another. Since the intent of the research was to identify local areas where the opportunities for residue recovery and use were optimum, it is impossible to identify an average or mean local situation. Additional local residue assessments would be needed before a good picture of the national situation could be ascertained.

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II. NORTHERN NEW ENGLAND ASSESSMENT

BACKGROUND

This is a summary of the series of studies that collectively form the wood residue assessment for northern New England--Maine, New Hampshire, and Vermont. Broadly, the assessment had the following objectives:

--Assess the existing inventory of potential forest residue.

--Assess existing demand for and supply of wood residue and predict future levels

--Analyze residue recovery and transportation costs.

--Assess the benefits and costs of increased residue utilization.

--Assess policies for reducing barriers to residue use.

The assessment was coordinated through the Northeastern Forest Experiment Station's Work Unit NE-4207 in Burlington, Vermont. Forest inventory and related data and analysis were supplied by Work Unit NE-4101 in Broomall, Pennsylvania. In addition, two cooperators were contracted for parts of the assessment. The principal investigators were Charles E. Hewett, Executive Director of the Maine Audubon Society and Thomas J. Adler, Professor, Thayer School of Engineering, Dartmouth College.

Several methods for data collection and analysis were used in the assessment. Standard field survey techniques were used to collect forest inventory data.

The line-intersect technique was used to collect data on wood residue on logged areas. A mail questionnaire and telephone survey were used by the Maine Audubon Society to collect information from non-residential fuelwood users and potential users.

Computer simulation was used to forecast future physical supply and demand for wood residues. It was also used to predict benefits and costs of greater residue utilization for fuelwood. Statistical cost analyses were used to evaluate residue recovery and transportation costs.

The northern New England States have a combined area of over 31.5 million acres with 83 percent classified as timberland. The major forest-type groups are spruce/fir and northern hardwoods in Maine, northern hardwoods and white/red pine in New Hampshire, and northern hardwoods in Vermont. Most of the timberland is in private non-industrial ownership (49 percent). Much of this land is in small parcels and many of the owners own and manage their land for reasons other than timber production. In Maine, the largest of the states, forest industry owns 40 percent of the total timberland. Public timberland makes up only six percent of the regional total.

Forest-based industry -- lumber and wood products, paper, and allied products, and wood furniture and fixtures -- has historically played a significant role in the region's economy and continues to do so. These industries employed over 55 thousand workers in 1981 and added over $1.5 billion in value to the local economy in 1978. The mix of forest and farm defines the rural character of much of the region and provides a base for the many industries that depend on tourism; a major source of regional income.

The New England States rank second to the Lake States in energy use per household, but the region pays more for it. New England's lack of traditional energy resources, its historic mix of high cost energy sources, its cold climate and rural character, are all contributing factors to high energy costs. The regional interest in wood energy from its abundant forest resource and wood

industry waste is a logical development especially in northern New England.

Two existing fuel chip users and their timbersheds were selected for detailed study of supply issues--the Burlington Electric Department's McNeil generating station in Burlington, Vermont and S.D. Warren Company's cogeneration plant in Westbrook, Maine. The Burlington Electric Department (BED) is a major public utility which generates electricity by burning wood at the McNeil generating station; a 50-megawatt plant which requires approximately 500,000 green tons of wood a year. S.D. Warren Company operates a kraft pulp mill in Westbrook which has a biomass fueled boiler. It uses 325 cords per day of roundwood and chips for its pulp and paper production. It also burns 1,900 green tons of chips and 200 tons of coal per day to operate a 45-megawatt generator that produces electricity for sale to the power grid and steam for its production operation. The McNeil station's timbershed includes six Vermont counties with a total area of 2.0 million acres. The S.D. Warren timbershed includes four Maine counties and a New Hampshire county with a total area of 1.9 million acres.

Fuelwood Supplies

Forest Survey data for Maine, New Hampshire, and Vermont were collected by the Forest Inventory and Analysis Work Unit of the Northeastern Forest Experiment Station in Broomall, Pennsylvania for use in the study. A computer simulation program (VWRAP) "grew" the trees on the forest inventory plots and provided data summaries at 10-year intervals. A harvest simulator, MANAGE, was written as a subroutine of VWRAP. MANAGE has two parts--PRESCRIBE and HARVEST. PRESCRIBE determined the silvicultural prescriptions or rules for managing a stand based on the stand's composition. Silvicultural guides sensitive to the species in the Northeast were used in PRESCRIBE. the subroutine HARVEST implemented the prescription if cutting was called for, assigned a site-specific harvest system, and estimated harvest costs.

From 1982 to 2012, as a result of using the silvicultural guides with the objective of producing high quality sawtimber, the simulated sawtimber volume increased 7.1 percent in the BED timbershed. An increase of 20 percent occurred in softwoods, while hardwoods decreased 3.5 percent. Hardwoods comprised 54.9 percent of the volume in 1982 and 49.4 percent in 2012. Net cubic-foot volume (net of sawtimber) decreased 7.0 percent over the 30-year period. Hardwood net cubic-foot volume decreased 8.8 percent and softwood volume decreased 2.7 percent.

In the S.D. Warren Company timbershed, the simulated sawtimber volume increased 53.3 percent. Hardwoods increased 104.5 percent, while softwoods increased 41.6 percent. Hardwoods comprised 18.6 percent of the volume in 1982 and 24.8 percent in 2012. The net cubic-foot volume increased 22.2 percent. Softwood and hardwood net cubic-foot volume increased 30.2 percent and 18.0 percent, respectively.

The total growing stock on accessible plots at the end of the 30-year period in the BED timbershed was 1.5 billion cubic feet. Hardwoods comprised 62 percent and softwoods 38 percent of the growing stock total. The average potential annual harvest was 38.7 million cubic feet, or approximately 2.5 percent of the total growing stock. Currently (1982), removals from growing stock for all uses average about 10 million cubic feet per year. Potentially, annual removals could be increased by a factor of four.

On the accessible plots in the S.D. Warren Company timbershed, the projected total growing stock was 2.3 billion cubic feet. Hardwoods made up about 45.9 percent of this volume and softwoods 54.1 percent. The average

potential annual harvest was 66.4 million cubic feet or 2.9 percent of the total growing stock. Currently (1982), removals from growing stock for all uses average about 25 million cubic feet per year. Potentially, annual removals could be increased by a factor of three. The implication for both timbersheds is that demand for traditional wood products would need to increase to capture the full potential embodied in wood biomass.

A change in diameter distribution for growing stock trees is expected during the next 30 years with an increase in sawtimber volume. The volume in trees 8 inches in diameter and less decreased from 24.8 percent of the total to 20.6 percent in the BED timbershed, and in the S.D. Warren timbershed, from 30.5 percent of the total to 18.2 percent.

Burlington Electric Timbershed--Assuming that the silvicultural guides for managing stands for sawlog production could be applied to all stands, regardless of ownership within the six-county area of the BED Timbershed, an estimated 5.6 million cunits of forest residue is potentially available at an extraction and transportation cost of $177.8 million (1982 $). The average cost per cunit is $32 and the range is from $21.50 to $56.50 per cunit. About 71 percent (3.9 million cunits) would be available for $33 per cunit or less. The remaining 29 percent would be available at between $34 and $59 per cunit. About 22 percent of this volume would require the use of cable yarding and chainsaw felling, because of slopes that are 30 percent or more. Production and transportation cost does not include an allowance for stumpage, overhead, and supervision. An additional $10 per cunit should cover these costs. Thus, 71 percent of the wood potentially available in the BED timbershed would cost $43 per cunit. This converts to about $2.70 per million Btu, which compares favorably with oil and natural gas at $6.20 and $3.90 per million Btu respectively, and is slightly more expensive than coal, at $2.10 per million Btu. All values are in 1982 $, based on the experience of New England industrial users, and were calculated on the basis of appropriate thermal efficiencies.

S.D. Warren Timbershed--Assuming that the silvicultural guides for managing stands for sawlog production could be applied to all stands, regardless of ownership within the five-county area of the S.D. Warren timbershed, an estimated 5.5 million cunits of forest residue is potentially available at a production and transportation cost of $154.7 million (1982 $). The average cost per cunit is $28 and the range is from $20.50 to $50.50 per cunit. About 84 percent (4.6 million cunits) would be available for $33 per cunit or less. The remaining 16 percent would be available at between $34 and $53 per cunit. Only 6.2 percent of the potential total volume would require cable yarding and chainsaw felling, which is necessary on slopes of 30 percent or more. This factor contributes to the difference in wood fuel cost between Maine and Vermont.

Logging Residue in Vermont--An assessment of logging residue was conducted in 49 commercially-harvested areas of Vermont. The line-intersect sampling technique was used to determine the volume and types of residue present. Mean volume of logging residue was about 264 cubic feet per acre with an expected deviation of ± 166 cubic feet per acre. Softwood stands yielded about 169 cubic feet per acre ± 76 cubic feet, while hardwood stands yielded 329 cubic feet per acre ± 180 cubic feet. The average piece was 3.4 inches in diameter at the small end, 6.1 inches at the large end, and 16.3 feet long. Because of the low per acre volume of residue and the small piece size, we concluded that it was uneconomic to reenter logged over stands to recover the logging residue.

Woodfuel Transportation Costs--Six factors that affect wood transport costs were examined: haul distance, load size, load type (chips vs. logs), the regulatory environment, inflation, and transportation mode. Data were provided by small and large trucking companies and the major rail companies operating in the area. The factor that effects transportation cost the most is length of haul. Average one-way haul distance for the truckers surveyed was in excess of 80 miles, while rail haul distance ranged from under 50 miles to over 300. The cost per ton-mile for truckers was 8.5 cents and for intra-state rail shipments was 5 cents per ton-mile. There was no price differential between transporting roundwood and transporting chips.

Truck capacity was about 22.5 tons, which represented the maximum legal load for semi-trailers on major highways (80,000 pounds gross vehicle weight). Railcar capacities varied between 50 and 60 tons, depending on car design. A modest-sized locomotive can haul up to 30 loaded railcars, achieving significant labor and fuel savings.

Two pieces of federal legislation, the Staggers Rail Act of 1980 and the Motor Carrier Act of 1980 have substantially deregulated inter-state rail and truck transportation. Most woodfuel shipments, however, are intra-state in nature, and many destinations are served only by truck. Since 1978, trucking costs for woodfuel have increased about 70 percent, while rail costs have increased 150 percent. By comparison, the Consumer Price Index has increased 65 percent and diesel fuel prices have increased over 155 percent during the same time period.

FUELWOOD DEMAND

The Maine Audubon Society used a mail questionnaire and telephone survey to collect information about non-residential woodfuel users and potential users. There are about 250 manufacturers, businesses, and institutions that use wood for energy in Maine, New Hampshire, and Vermont. Wood use for electric power production by both public and private utility companies is growing. In northern New England, the 2.7 million green tons of woodfuel consumed in 1980 represented 7 percent of the non-residential combustible fuel total. Pulp and paper mills consumed 52 percent of the total, lumber and wood product plants consumed 13 percent, small non-forest products plants consumed 29 percent, and electric utilities consumed the remaining 6 percent.

In 1983, Dartmouth College developed a computer simulation model called CHIPS. The model estimates future wood energy use based on projections of critical trends in energy consumption and fossil fuel prices that assist in determining the economic attractiveness of wood energy investments. It also indicates how sensitive the region's woodfuel market would be to changes in these trends.

Using the CHIPS simulation model, a base case forecast of woodfuel use from 1982 to 2012 was developed. The results show that the woodfuel market will grow in three distinct phases during the next 30 years; first a brisk and steady growth will occur through the 1980's, then a flat market with very slow growth will characterize the 1990's, and finally a steady and modest growth will take place at the turn of the century. Between 1982 and 1992, total woodfuel consumption will grow by about 75 percent, followed by another increase of 25 percent by 2012. Woodfuel prices will rise from $17 per ton in 1984 to $25 (1982 $) per ton by 1992.

The largest increase in woodfuel use is expected in the pulp and paper sector. The current trend of converting from oil to wood will continue until solid wood fuels represent about 40 percent of the market share in 1992. A significant

increase in woodfuel use is not expected in the lumber and wood products sector since it has already achieved 80 percent energy self-sufficiency by utilizing mill wastes.

Large non-forest products industries accounted for only 3 percent of the total non-residential energy consumption in the region in 1982; however, energy use in this subsector is expected to grow rapidly. A doubling of woodfuel consumption is expected between 1982 and 1992, which would result in woodfuels providing 14 percent of the energy consumed by this subsector in 1992.

The small non-forest products industries accounted for 55 percent of total non-residential energy use in 1982. Total energy consumption in this subsector is expected to remain flat during the next 30 years as economic growth is offset by improvements in energy efficiency. Nevertheless, woodfuel consumption in this subsector will increase 50 percent from 1982 to 1992. A growing market share for coal is also projected for this subsector, primarily due to a lack of awareness of wood energy alternatives and expectations of rising wood prices in contrast with declining coal prices.

BARRIERS TO WOOD ENERGY DEVELOPMENT

There are two types of barriers that can constrain the development of the wood energy market. The rate of investment in wood systems can be slowed by a set of user barriers that influence investment decisions by individual firms. These include: technical issues relating to energy system design, installation, and operation; financial issues, including equipment costs and capital availability; and management concerns including system reliability, fuel supply security, and environmental regulations.

The level amount of investment that can be achieved and sustained in the region will also be determined by a second set of factors that constrain the overall market and influence current and potential users. These market barriers include: economic limits to the use of wood as an energy resource; adverse effects on environmental quality; and increasing public concern about competing uses for the forest resource.

A key technical issue in the study region is the increased traffic congestion, added infra-structure maintenance costs, and elevated noise levels that can result from transportation of fuelwood. Traffic flow on highways may be impeded by added truck traffic but it depends on existing traffic flow and road grade. As the physical capacity of the highway is approached, added truck traffic on highway intersections is in many ways analogous to the effect on continuous highway segments. Truck engine noise and tire-roadway interaction noise may make locations near roadways undesirable places to work or live. Roadway noise levels are often the stimulus for negative community response.

WDTRANS (Wood Transport Analysis System)---a micro-computer-based model--was developed to assist in evaluating the cost and external impacts of truck transportation of wood to a wood-using facility in the Northeast. The model is implemented on a popular spreadsheet program available on many microcomputers. With some changes in model parameters it could be adopted for use in other parts of the country. Program outputs include: number of cords of wood required annually, number of truckloads per day, annual trucking cost, added highway maintenance cost, noise impacts, and traffic impacts at the plant's entrance.

IMPACTS OF INCREASED WOODFUEL USE

Increased woodfuel consumption will affect the region's energy security, economic development, employment,

income, government revenues and expenditures, forest resources, and environmental quality. The energy economy provides jobs, income, and government revenues; directly, as a result of the construction, operation and fuel procurement for energy systems; and indirectly, through the multiplier effect of money spent on goods and services by energy-related firms and employees as it circulates through the economy.

Between 1982 and 1992, we expect a 27 percent increase in total energy employment in northern New England. This will be the outgrowth of a projected increase in total energy consumption and, to a lesser extent, due to the creation of new jobs as consumers shift from oil and gas to wood and coal energy. A 75 percent increase in woodfuel consumption is projected between 1982 and 1992, as woodfuel consumption increases from 7 percent of total fuel use to 12 percent. This will cause an increase in total energy employment, primarily in businesses involved in woodfuel procurement. Employment in the wood energy economy is expected to increase 46 percent, from 4600 people employed to 6420. Wood energy employment accounted for 35 percent of total energy employment in 1982. This is expected to increase to 39 percent by 1992.

During the same period, wood-energy-related income is expected to grow 12 percent from $249 million to $280 million. Total energy-related income is also expected to increase 12 percent, from $676 million in 1982 to $756 million in 1992. The displacement of oil by woodfuels may result in lower total state revenues, because the amount of sales tax paid per barrel of oil may not be offset by the increase in public revenues from woodfuel procurement activities.

Five alternative scenarios were developed to evaluate the sensitivity of the woodfuel market to changes in the regional economy. Several trends and issues were identified in these forecasts. For example, the region's woodfuel market can accommodate additional capacity for large wood-fired electric generating plants without significant effects on other users except in local instances. The New England woodfuel market is somewhat sensitive to changes in natural gas and coal prices. Higher fossil fuel prices would lead to greater demand for wood energy. The woodfuel market is linked in a complex manner to the region's forest products industry.

Changes in forest industry development could impact woodfuel markets differently in the short-term than in the long-term. If pulpwood demand remains relatively stable increased wood energy investments by the non-forest products industry might be stimulated in the short-term. In the long-term, reduced demand for energy in the forest products industry would offset increased woodfuel use by the non-forest products industry. Alternatively, higher growth in the forest products industry's demand for pulpwood would cause increased woodfuel prices and fewer wood energy investments by the non-forest products industry in the short-term. In the long-term, harvesting capacity would expand, fuel prices would drop, and investments in wood energy would increase in both the forest products industry and the non-forest products industry.

TECHNOLOGY TRANSFER

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Computer Program Developed

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Conferences (planned)

Workshop(s) for non-residential wood energy users coordinated through State and Private Forestry, U.S.D.A., Forest Service.

III. THE PIEDMONT REGIONAL ASSESSMENT

BACKGROUND

The Piedmont assessment focused on an 18-county area that comprises approximately the northwestern third of South Carolina. The selection of this group of counties resulted from joint consideration of several factors. The area is to some degree geographically discrete because it is bounded on the southwest by the Chattooga, Tugaloo, and Savannah Rivers (the Georgia State Line) and on the north by the Southern Appalachian Mountains. The counties form an entire Forest Survey Unit, which insures that certain summary data are readily available. A previous study by Harris (1982) had already indicated a wood surplus in the six most northwesterly counties.

The area is entirely Piedmont Plateau except for a narrow fringe in the edge of three counties that lies in the mountains along the Blue Ridge Escarpment. About 68 percent (4,566,782 acres) of the total area is forested (Snyder 1978). Less than one percent of the forest land is classified as "productive-reserved" and the remainder considered commercial. We define commercial forest land as forest land producing, or capable of producing, crops of industrial wood, and not withdrawn from timber production. Forest industry owns only 13.2 percent of the commercial forest land. The largest landowners are farmers and miscellaneous private individuals who own 34.7 and 32.3 percent of the area, respectively. Other owners include miscellaneous corporations, 10.3 percent; National Forests, 7.5 percent; other federal, 0.9 percent; and state and local governments, 1.1 percent. The percent of commercial forest area by forest-type groups are:

Forest-Type group	Percent of area
Lobolly-Shortleaf Pine	49.4
Oak-Hickory	32.5
Oak-Pine	14.9
Elm-Ash-Cottonwood	2.8
White Pine-Hemlock	.3
Longleaf-Slash Pine	.1

Most of the land area except for the wettest areas, has been farmed. Hence, forest type and condition have been strongly influenced by the sequence of agricultural abandonment, natural succession, and logging of the higher quality timber for wood products. A substantial proportion of the remaining hardwoods are inadequate for conventional wood products. The value of the logs in some of the oak-hickory and oak-pine stands is less than the cost of logging. Although conversion to pine in some of these stands would be preferred, the projected return on investment precludes it. The option of marketing this material for fuel would be desirable and also add to the overall productivity of the commercial forest (McMinn 1985).

Although the assessment was for a specific area, the approach consisted of exploring and using methods that would apply to the entire Piedmont of the Southeast. In addition to USDA Forest Service Research Work Unit SE-3101 (Utilization of Southern Timber), four universities participated in the assessment; Clemson University, the University of Georgia, Virginia Polytechnic Institute and State University, and Western Carolina University.

FUELWOOD SUPPLIES

There are six sources of wood residues in the Piedmont: (1) logging residue and noncommercial stands, (2) land conversion, (3) precommercial thinning, (4) salvage, (5) primary mill residues, and (6) surplus growing stock. It was not considered feasible to recover residues during precommercial thinning, so that source of residue was omitted from the estimates. Residue estimates from logging and noncommercial stands, salvage, and surplus growing stock were based on retrieving information from the Forest Inventory and Analysis (FIA) Unit's data base and from published forest resource statistics. Residues available from land conversion were estimated from additional data provided by the FIA Unit. Primary mill residue estimates were obtained from a 1982 Commodity Drain Survey conducted by Clemson University Forestry Extension Service.

The FIA Forest Information Retrieval System provided estimates by cover type for three six-county groups, because statistically-reliable estimates could not be generated by FIA for smaller areas. Data for each six-county group were apportioned among the individual counties according to the ratio of forest acreage of the county to forest acreage of the group. The distribution of forest acreage in each county among major forest cover types or broad management groups was based on Snyder (1978). FIA estimates of recent past treatment provided a basis for assuming the fraction of each cover type that would contribute to residue production.

A detailed breakdown of residue type by county was compiled and used as input for the part of this project relating to the potential impact of increased woodfuel use and its relation to the price and availability of wood for conventional products.

Overall estimates in thousands of green tons per year were:

Forest residue and noncommercial stands	6,770
Land conversion	225
Salvage	919
Primary mill residues	1,020
Surplus growing stock (not considered a residue in supply/demand model)	7,164
	16,128

Two exploratory studies were conducted in addition to the above effort. The first dealt with use of available digitized elevation data in conjunction with satellite imagery to adjust forest residue estimates on the basis of slope. The intent was to deduct from estimated residue that fraction in each forest type that occurs on slopes greater than a specified operability threshold. This effort was unsuccessful because the digital terrain model was not sensitive enough to slope and the satellite land cover classification failed to distinguish between nonforest and forest land. Land with fence rows, orchards, and residential subdivisions were frequently classified as mixed upland hardwood--the forest type of highest priority for energy use in the Piedmont. If a slope-related deduction for availability is to be made, the best data source is the slope estimates recorded by FIA field crews.

The second exploratory study dealt with development of biomass prediction equations for use with 1:24,000 scale color infrared monoscopic photography. An equation of low reliability (coefficient of variation of 36%) was found to be just as reliable as equations for specific forest types in predicting total biomass. By applying this equation to different forest types and conditions, a forest residue fraction for each set of conditions could be calculated and a total biomass estimate made.

FUELWOOD DEMAND

A primary objective of this analysis was to establish a general framework by which potential regional demand for wood energy could be derived from public information. The strategy was to employ financial equations for cash flow analyses of alternative energy systems in existing industries. The underlying rationale was that industry is by far the largest energy consuming sector (about 65% statewide) and the financial environment is the driving force behind system conversion. Large firms (those with 50 or more employees and at least one boiler with a capacity in excess of 20,000 pounds of steam per hour) were targeted. Over 100 large firms were identified in the study area from the National Emissions Data System and the South Carolina Industrial Directory. An additional constraint was that the financial analysis had to indicate a maximum payback period of 3 years. These criteria identified installations that are good conversion candidates.

The cash flow analysis was based on the "Wood IV" system published by the N.C. Department of Commerce in the Wood Energy Information Guide. The model generates net cash flow values using the engineering aspects of the system, fuel characteristics and prices, and financial variables that include federal and state taxes and credits. Regional values were used for boiler capital and maintenance costs.

Payback periods were derived for a range of boiler system sizes under different sets of assumptions. The critical system size for each set of assumptions was used in conjunction with regional energy consumption per employee to determine an upper limit for system size. A number of demand estimates were developed by varying over a "reasonable range" assumptions regarding interest rates, oil prices, wood prices, and higher base prices for both fuels. The estimates ranged from 0.6 to 3 million green tons in the intermediate term with the most likely level approaching 1.5 million green tons per year.

BARRIERS TO WOOD ENERGY DEVELOPMENT

According to a General Accounting Office report, four barriers appear to have a significant effect on residue use nationwide. They are:

1. Inadequate data on the volume, location, accessibility, and availability of forest residues,
2. Lack of economical and effective equipment for harvesting and transporting residues,
3. Lack of investment capital needed for harvesting and using residues, and
4. Limited awareness and acceptance of wood energy and product technology among industrial firms, utilities, and state and local bodies.

Three other obstacles were judged by GAO to discourage or prevent residue use in some areas around the country. They relate to:

5. Federal forest management policies and programs,
6. Utility practices and regulations, and
7. Environmental concerns related to greater use of residues.

The Piedmont assessment did not address barriers explicitly, however, of the seven items above, only items 4 and 6 significantly influence residue use in the Piedmont. Lack of awareness has been, and remains, a barrier in this study area. This perception is reinforced by the greater intensity of wood energy use in the adjacent states of Georgia and North Carolina; both states had

aggressive wood energy promotion programs since 1978. In addition, South Carolina, which derived 36 percent of its electrical energy from nuclear reactors, is a major energy supplier in the study area. Had that commitment not been made prior to the OPEC scare of the early 1970's, wood might have been considered more seriously either as an electrical power source or as an industrial energy source.

IMPACTS OF INCREASED FUELWOOD USE

This element addressed the relationship between increased wood-fuel use and the price and availability of wood for such conventional products as pulpwood, saw logs, and veneer logs.

The demand for conventional products was derived from the South Carolina Commodity Drain Survey conducted annually by the Clemson University Cooperative Extension Service. Data from 1972 to 1981 were used to determine annual production for pine and hardwood products by county. The survey information was also used to determine the conventional product mix, industrial capacity, delivered value, and unit price. Industrial capacity for each product was estimated by summing the maximum annual production in each county in the 18 county area during the 10-year period.

An alternative approach for calculating forest residue concentrated on the available wood fiber generated as a byproduct of conventional harvesting. An approximate volume of conventional material per acre was calculated together with an estimated residue quantity associated with products harvested from the pine, pine/hardwood, and hardwood types. These values, together with a known quantity of products from the commodity drain survey, permitted the estimation of acreage harvested and residue volume. Demand for fuelwood was from Harris (1982) and from the analysis discussed in the fuelwood demand section.

Pine pulpwood is the largest conventional product category with an average annual production of over 2.5 million green tons; approximately double the next largest category, pine sawtimber. Hardwood sawtimber and pulpwood combined averaged just under 1 million tons per year. Overall production averaged over 5 million tons annually for the 10-year period, with a range from 4,212,340 to 5,636,455 tons. The derived maximum capacity is approximately 6 percent greater than the highest single-year production, which occurred in 1976. Estimated post-harvest residue ranges from 3.2 to 4.3 million tons annually. In 1981, the estimated acres harvested based on product output was 176,000. This estimate is fairly consistent with the 189,000 annual acreage derived from FIA data for this category of residues. Since the potential demand for residue ranged from about 0.6 to 3 million green tons annually, this single residue source could theoretically satisfy the demand.

A number of industrial plants in the region that are considering new solid fuel combustion systems have found that the cost of wood is approximately equal to the cost of coal. The ceiling price for woodfuel may depend on the price of coal rather than oil and natural gas. Current (1982) delivered woodfuel prices range from about $14-$18 per green ton. This price equals the delivered price for hardwood pulpwood. Greater fuelwood demand than anticipated in this study will pose no problem for pulpwood availability, however, and the probable effect on the sawlog market is to simultaneously lower costs and increase quality. Our reasoning is that more acreage would be harvested and, because of the value difference, sawlogs would be marketed separately by the producer rather than included in the fuel mix.

FEASIBILITY OF REGIONAL IMPLEMENTATION

It is often assumed to be uneconomic to transport residues more than a very short distance, a 20-30 mile maximum. However, a recent study in Georgia (Eza et al. 1984a) showed that from a practical standpoint transportation is not a limiting factor. The same allocation model that incorporates transportation costs was applied to the assessment study area.

The analysis utilized a supply-demand allocation model called the "Wood Residue Distribution Simulator" (WORDS). The model was originally a recreation allocation model that was modified to handle unused primary manufacturing residues in Georgia (Eza et al. 1984b). WORDS uses purchase and delivery costs for residues as a measure of supply attractiveness. Supply costs include the cost of extracting and transporting the material to the energy conversion site. WORDS systematically allocates raw material in such a way that a least-cost overall allocation is achieved. The current version allocates until either all of the raw material is exhausted or the total requirement is satisfied, but prevents allocation of any raw material that has a higher cost than some specified alternate energy source. The total cost of acquiring and shipping wood-fuel from each supply point to each energy conversion site is also calculated. The WORDS model requires the following inputs: (1) quantity and cost of each type or combination of residues at each supply point, (2) transportation costs specified as some function of distances between supply and conversion site, (3) alternate energy costs at each conversion site. Conversion sites raw material locations are divided into up-to-9 preference categories according to the delivered costs of raw material. The user specifies the cost boundaries for each preference class. The model will handle several categories of material at each of 160 potential raw material and conversion locations.

To evaluate the model for this application supply and demand values were taken from previous analyses. The four wood residue types were used in this analysis. The types, quantities, and their calculated costs at the raw material locations were:

Type A: forest residues recovered by integrating existing roundwood operations to harvest tops, branches, and small trees; 6.77 million tons; $27/ton.

Type B: forest residues recovered from noncommercial forest land conversion; 0.255 million tons; $18/ton.

Type C: forest land salvage operations; 0.919 million tons; $18/ton.

Type D: primary manufacturing residues; 1.02 million tons; $12/ton.

Surplus growing stock was not considered a residue in this analysis. Wood energy values were derived from published information and transportation costs from published information and a survey of wood products transporters in Georgia. Ten scenarios were used to evaluate general wood energy feasibility in the study area. Table 1 summarizes the assumptions used in each scenario. An alternate energy price of $6.25 per million Btu is the equivalent of natural gas at $5.00 per thousand cubic feet and 80 percent efficiency.

The first three scenarios allocated all of the wood residue material at a favorable cost (table 2), but none fully satisfied the overall demand of 1.5 million tons. The fourth scenario used the two least expensive residue types, which together would satisfy total demand. This scenario indicates that even at an upper boundary for demand estimates, wood energy could be supplied at a significantly lower cost than natural gas energy. Scenarios

Table 1.-Scenario Structures

Scenario	Residue type	Alternate energy cost	Wood prices	Comments
		$/MMBtu		
1	IV[1]	6.25	base	
2	III	6.25	base	
3	IV	6.25	base	
4	III,IV	6.25	base	
5	II,III,IV	6.25	base	
6	I,II,III,IV	6.25	base	
7	III,IV	9.38	base	
8	III,IV	6.25	1.5 base	
9	III,IV	6.25	base	First allocate III, then allocate IV.
10	III,IV	6.25	base	Using $2 rather than $5 preference classes.
11	III,IV	6.25	base	Add simulated power plant. 410,000 Tons/Ann.
12	III,IV	6.25	base	Using LP.

1/ I=forest residue, II=land conversion, III=salvage, IV=manufacturing residue.

Table 2.-Summary of simulation results

Scenario	Minimum		Maximum		Average cost
	Cost	County	Cost	County	
	$/MMBtu		$/MMBtu		$/MMBtu
1	$2.63	Oconee York	$3.34	Lancaster	$2.91
2	3.92	Edgefield	4.17	Greenwood	4.07
3	3.91	Edgefield	4.17	Cherokee	4.06
4	3.06	Saluda	3.60	Spartanburg	3.38
5	3.06	Greenwood	3.64	Spartanburg	3.41
6	3.87	Newberry	5.03	Anderson	4.51
7	3.06	Saluda	3.60	Spartanburg	3.38
8	3.96	Newberry	5.19	Greenville	4.59
9	2.63	Oconee	3.88	Spartanburg	3.30
10	2.80	Newberry	3.67	Cherokee	3.25
11	3.06	Saluda	3.75	Power Plant	3.48
12	2.80	Newberry	3.69	Lancaster	3.19

five and six added successively more expensive residues to the allocation pool. Scenario seven used a natural gas price of $7.50 per thousand cubic feet. Scenario eight added 50 percent to the wood residue purchase price and maintained transportation cost at the same level.

The last four scenarios were intended only to evaluate WORDS for this type of general problem, since the preceding scenarios had already indicated the high potential for the model in the study area. Note that the last scenario used a linear programming formulation to find the absolute least-cost allocation, but this result is much more expensive than the simulation approach. Simulation expense and accuracy are both affected (in opposite directions) by the specified width of preference classes.

WORDS may be used without modification to evaluate raw material/conversion site networks in other geographic regions. The model currently permits up to 160 conversion locations, 160 raw material locations, and eight types of material. These variables may be allocated singly or in any user-specified combination. This particular assessment aggregated both supply and demand to the county level, but the level of aggregation is up to the user. The physical size of raw material units or residue conversion units need not be the same and the user may subdivide a system in any way as long as raw material units do not overlap and conversion units do not overlap. The number of raw material units does not have to equal the number of conversion units.

TECHNOLOGY TRANSFER

One paper has been published on the biomass estimation element of this project (Nix et al. 1984) and a Forest Service General Technical Report similar to this document is planned. In addition Robert Harris of Clemson University plans to publish a journal article on the potential impact on conventional wood products.

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IV. NORTHEASTERN MINNESOTA ASSESSMENT

BACKGROUND

Minnesota has one of the highest per capita energy uses in the Nation, but has no coal, oil, or natural gas. Yet it has a vast underused forest resource that could meet a significant portion of its energy requirements with little additional assistance or incentive. The comprehensive study of the situation in northeastern Minnesota:

1. Examined the impact of increased wood energy use on the supply costs of all forest products.

2. Determined current markets for industrial, commercial, institutional, and residential energy.

3. Determined the potential economic and social impact of increased wood energy use by various sectors.

4. Identified alternative public policies to stimulate greater wood fuel harvest from Federal, State, county, and private lands.

5. Identified barriers limiting the use of woodfuels.

The study area consists of seven counties in NE Minnesota; Aikin, Carlton, Cook, Itasca, Koochiching, Lake, and St. Louis, comprising an area of about 11.5 million acres. Commercial forest land totals 7.4 million acres or 65% of the total and varies widely by cover type and ownership.

Public forest lands comprise about two-thirds of the region; 23% Federal, 21% State, 22% county, 10% forest industry, and 24% other private. Hardwood cover types comprise 60% of the total, and softwoods, the remainder. Aspen and paper birch types cover 60% and 17% of the hardwood area, respectively. Balsam fir/white spruce types cover 31% and 33% of the softwood area, respectively. Almost all cover types are heavily mixed with hardwood and softwood species. A major concern of forest managers is the advanced age distribution of the aspen, paper birch, and balsam fir/white spruce types; 53%, 86%, and 65% respectively, exceed 40 years.

Previous efforts to characterize industrial opportunities for this timber have often emphasized favorable growth-removal relationships. One recent estimate using this approach found that total net growth of all species in the area was about 115 million cubic feet per year compared to estimated removals of about 77 million cubic feet, leaving an annual surplus of about 38 million cubic feet. Increased harvests would presumably reduce this surplus and enhance future management opportunities.

Current mortality in this area is roughly 56 million cubic feet, due largely to the mature and over-mature character of this region's forests. Gross growth was about 171 million cubic feet, some 49% greater that net growth. If this mortality were captured by timely harvest, the surplus would have been some 94 million ft^3, about 3 times greater. Under current age class conditions, expanded harvests are called for, not reduced ones. Growth-removals ratios are relevant only for managed or regulated forests and northeastern Minnesota's forests do not yet meet this criteria.

Biological opportunities, however, are not the same as economic supply. Simply having a large inventory, or the prospect of an even larger one in the future, does not mean that we should, or even could, use it. Stand location and access to market, site index, existing stocking, species mixtures, harvest costs, and regulatory

restrictions all interact to determine economic harvest levels. Many of the economies of recovering currently unused wood will take place only if we can recover it along with traditional sawlogs or pulpwood. This study focused on timber supply in this broader economic perspective.

Northeastern Minnesota is currently a focal point of changing forest resource management perspectives. Each of three major public agencies are looking for opportunities to address their budget limitations, to improve wood utilization, to respond to regional economic growth initiatives, and to provide greater socio-economic justification for their programs. Wood energy development is attracting great interest and prospects for large and enduring impacts are good.

FUELWOOD SUPPLIES

While the pulp and paper industry is the largest wood user in northeastern Minnesota, a new waferboard industry has expanded significantly. Both use aspen, an abundant species. However, the projected increase in demand raises concern about its future supply. Recent studies suggest significant shortages in 20 to 50 years if current harvest trends continue. Wood energy development can improve the long-term wood supply outlook for aspen.

Current forest conditions resulted from past actions. The region's conifer forests were first logged in the early 1900's. Natural regeneration resulted in mostly even-aged, mixed hardwood and conifer stands. The current species mix affects stand values dramatically. The price for standing timber can vary by a factor of 10, depending on the abundance of unwanted species. Harvests are not economic if significant quantities of unwanted species are present. Unwanted species also create long-term problems, occupying sites that could support more valuable species.

How would a large wood energy market affect existing timber markets? In the short-run, a wood energy market using unwanted timber could make previously uneconomic mixed stands profitable to harvest. In the long-run, a wood energy market would permit the removal and replacement of previously uneconomic stands with desirable stands which would help satisfy future timber product demand.

Other factors must be considered for their competitive impact on timber prices and wood allocation. For example, wood energy markets are often located at sites that differ from ordinary timber markets. Because the transport cost is often half of the delivered cost of fuelwood, a stand's location might make it more advantageous to use some wood for energy that would otherwise be shipped to other wood markets. A strong wood for energy market could also result in small volumes of high-value timber being chipped for energy, simply because product segregation would not pay. Of course, these are serious concerns for existing forest industry.

Because all stands, regardless of productivity or location, may be needed to contribute to the future timber supply, we needed to know more about scheduling future harvests. This meant taking the unregulated forest, with its unbalanced age distribution, and determining the least-cost schedules for achieving a desirable harvest level over time.

In ranking management opportunities, we applied a new harvest scheduling model to all land ownerships in northeastern Minnesota to estimate the marginal costs of major product groups (sawlog, pulpwood, and wood energy) over time and at various product output levels. We developed several scenarios describing plausible future harvest levels, identified management alternatives and costs for each cover type, and chose the least cost set of management alternatives. Marginal costs for each harvest level were

examined to assist in determining the dollar outlay required to make the alternative timber investments profitable. In this study we examined the interaction of the marginal cost for traditional forest products and for wood energy.

The approach (developed by Howard Hoganson and Dietmar Rose) is a simulation based on an economic interpretation of the key dual variables of a linear programming (LP) formulation of the problem. These key dual variables (marginal costs) are interpreted as "shadow prices" for producing each product during each period. The initial step requires estimating these shadow prices. The dual problem is then decomposed and solved with dynamic programming. The "primal" harvest schedule implied by these shadow prices is next tested for feasibility by comparing it to the "desired" harvest schedule. If the two harvest schedules differ, the key marginal costs are adjusted and the process repeated until the "primal" harvest schedule matches the "desired" harvest objectives.

In economics, shadow prices are used to value resources for which market prices do not exist, or to reflect either society's opportunity costs foregone or society's actual willingness to pay. These conditions often apply in forestry, especially where public resources are involved, and where buyers use only a small portion of the total resource.

Conventional LP models for timber management scheduling rapidly increase in size as new stand information is added. These models also seek an exact solution to the problem. Because future production levels are impossible to predict with certainty we developed a new process which accepts so-called near-feasible solutions. Thus computer time was saved and the computational efficiency of dynamic programming was increased so we could consider larger, more realistic problems.

Over 6000 stand types were considered in our study. Detailed information was gathered on growth and yield, forest management alternatives and costs, existing and potential market locations and sizes, and current and forecasted forest product demands. About 5000 permanent Forest Survey plots were used to describe initial forest conditions. The geographic coordinates of each plot were used with a road grid to calculate relative distance (close, medium, and far) to either an energy market or existing wood market. All cities with a population of 2000 or more were assumed to be an energy market. Their location and an estimate of demand were obtained from a number of sources.

Twelve site types were recognized. Types were segregated by soil productivity and by the species that could be regenerated naturally. Each type was subdivided into as many as 10 classes based on species and their relative abundance and value. Site and species mixes were further divided by stocking level (high or low) and age. Both silvicultural and economic characteristics were considered where various classes had to be aggregated.

Growth and yield data were difficult to obtain because very little information is available on the growth of species mixtures. For example, many existing growth and yield models aggregate all stands in which aspen predominates with little regard to the other species present. Long-term growth projections are especially weak. Data for this study were developed by Alan Ek and Jerrold Hahn who combined current Forest Survey data and growth model projections to create empirical yield tables. A program was then written to prepare management prescriptions based on the empirical yield tables and included the timing of all costs and returns. All prescriptions required clearcuts, however, the harvest systems were varied. They included traditional roundwood-only systems, full-tree chipping systems, and chip and sort

systems. Harvesting costs were estimated from data provided by Robert Hazenstab and James Bowyer.

Twelve forest products were considered by varying three material types (sawlogs, pulpwood, and branches and tops) and four species groups (aspen, valuable softwoods, other softwoods, and other hardwoods). These types were then aggregated into three groups: aspen roundwood, softwood roundwood, and wood energy.

Future consumption levels for aspen roundwood and softwood roundwood product groups varied from current levels (5.5 and 4.0 million cunits per decade) to 9.0 and 8.0 million cunits per decade. Also wood energy output levels from 1 to 30 million dry tons per decade were examined.

Dynamic programming then linked first-rotation harvest alternatives for the initial stand types with regeneration options. Both natural and artificial regeneration were considered. A "non harvest" option assumed that if the initial stand was not harvested, it followed natural succession toward either a climax hardwood or softwood type. Once harvested, the natural regeneration options were based on the growth and yield data developed for the initial rotations.

Our study of the effects of wood energy development in NE Minnesota shows what could be, rather than what should be. We concluded that the impact of increased wood energy use would be greater on aspen than on softwoods. In fact, softwood supply costs were affected very little. While short-run aspen supply costs were sensitive to wood energy level, long-run aspen supply costs would be reduced with increased wood energy use. The long-term impact on aspen was simple: wood energy markets lower fixed and variable costs of all wood products because a slow-growing, overmature, poorly stocked area has been replaced with a well-stocked, rapidly growing stand.

FUELWOOD DEMAND

A regional input/output model of the seven county area was used to measure the nature of current energy use, as well as the impact of potential changes. The model identified 215 sectors and their purchases of coal, petroleum, and natural gas. We focused on 31 sectors, however, that accounted for 97, 89, and 95 percent of the fuel consumption, respectively. We calculated wood requirements and cost savings for several levels of fossil to woodfuel conversions using a custom micro-computer spread sheet. These conversions in turn were used to create a new wood energy sector for the input/output model. New transaction tables, including the smaller fossil fuel purchases and larger woodfuel purchases, were inverted resulting in direct and indirect effects tables. These tables contained the output multipliers and allowed a "before and after" comparison of wood energy development. Portions of a related model (SIMLAB) were also used to calculate "before and after" employment multipliers.

Total fossil fuel use was about $280 million in 1977; 11% coal, 61% petroleum, and 28% natural gas. These values do not include transportation fuel costs. The largest base line sectors are iron mining, 16%; forest industries, 10%; petroleum refining, 9%; electric utility, 13%; gas utility, 8%; and households, 19%. The most likely scenario for conversion would be for the iron mining, forest industry, and electric utility to use coal. These sectors accounted for 87 percent of the total coal use and 10 percent of all fossil fuel use. We assumed that about one-third of coal use could be replaced by about 1.600 million green tons of wood per year.

The next most likely conversion opportunity was the use by several sectors of fuel oil for heating and processing. Major sectors where substitution would occur include forest industries, retail trade,

health services, government, and households. These sectors accounted for about half of the total fuel oil use and a third of all fossil fuel use. We assumed that about one quarter of fuel oil could be replaced by about 1.965 million green tons of wood per year.

Major sectors for natural gas conversion would be electric utilities, the wholesale and retail trade, health services, households, and government. These sectors used about one third of the natural gas total and 9 percent of all fossil fuel. We assumed that about 17 percent of the natural gas would be replaced by about 1.162 million green tons per year.

In total, for either of two scenarios, about one quarter of all fossil fuels would be replaced by about 4.743 million green tons of wood per year.

If conversion costs are excluded, wood is currently less expensive than fuel oil and natural gas, and coal is less expensive than wood, except for the residential sector.

BARRIERS TO WOOD ENERGY DEVELOPMENT

We identified four kinds of barriers: technical, financial, institutional, and attitudinal. The first two are being rapidly solved. Not that we did not know how to burn wood previously, but the high combustion efficiency, low cost, and convenience of fossil fuels have been a significant obstacle. Much has been accomplished on the technical side and price differences have narrowed or disappeared. There are always concerns about the wood supply. Questions raised by wood consumers depend on resource professionals for answers. Many land management agencies have not recognized that regional and national resource analyses are sometimes contradictory. Resolving the technical questions of shortage vs. surplus in regional analyses is an important step in addressing the nationwide problem of low energy wood use. Some agencies view the use of wood for energy as an inferior use. Resource professionals should welcome additional wood use opportunities and allow the free market pricing system to determine the allocation of the resource.

An extensive list of programs and policies that could encourage wood use for energy was compiled. These policies were rated on the basis of several criteria, but were not ranked. The technical and financial obstacles are being addressed. At present the government is poorly equipped to deal with these policy changes. The regulatory and administrative perspectives, often based on traditional but arbitrary rationales, are fertile grounds for change.

IMPACTS OF INCREASED FUELWOOD USE

Currently we have adequate wood for energy, but unless it is used, wood energy costs will probably increase. Our two conversion scenarios suggest that an annual wood requirement of about 4.7 million green tons per year could be sustained. This level is where wood energy demand is complementary, especially in the long-run, when both aspen and softwood demand are expected to increase. At higher wood energy levels (7 million green tons per year) wood costs may increase slightly in the short-run, but would decline even more in the long-run, as compared to the 4.7 million green tons use level. This would be good news for resource managers who are concerned about future wood supplies.

There are four kinds of social economic impacts of converting to wood: 1) increased regional employment; 2) increased regional output; 3) fuel cost savings; and 4) induced impacts.

First, the two scenarios would create about 2,000 new jobs, a 1.5 percent increase. About 400 of these job would occur directly in a wood energy

sector. These job increases are not quite as large as would be expected, but seem reasonable considering the high underemployment in the forest sector.

Second, regional output would increase about $100 million (1977 dollars), a 2 percent increase. About $50 million of this increase would occur directly in the wood energy sector. Here again the 2 percent gain in total output compared to only a 1.5 percent gain in total employment is additional evidence of the high underemployment which characterizes much of this area's logging and wood transport sectors.

Third, fuel cost savings of the two scenarios would be about $15 million (1977 dollars) which is about 5 percent of total fuel costs. In 1980 dollars, this would be about $55 million, about 10 percent of total fuel costs.

Fourth, while the input/output model we used could not show it, fuel cost "savings" would induce added regional growth in output and employment because these savings would be available to be spent for other things.

IMPLEMENTING WOOD ENERGY DEVELOPMENT

Wood energy development will require both individual and public and private action. Because of the prevalence of public lands in NE Minnesota we would expect most of the critical initiatives to come from the several state, county, and federal land managers in the region. Regarding wood supply, it will depend on how wood energy is viewed in relation to traditional forest product use. If the supply is perceived to be limited or the real price for saw logs and pulpwood exceeds wood energy prices, we expect that timber sale and pricing policies would not change.

Our assessment of the long term forest resource situation in NE Minnesota shows 1) a resource surplus, as evidenced by both real price declines and expanding inventory; 2) an imbalance in stand structure, with most of the area concentrated in the overmature age classes that experience high mortality rates; 3) the imminent loss of the sunk costs of growing and protecting these stands over the last 60 years unless they are harvested soon; and 4) high future wood costs if the opportunity to use these stands is not realized and regeneration implemented for future timber crops.

Instead of selling small quantities of timber, large long-term sale and pricing agreements should be considered. Long-term coal, oil, and gas leases have been negotiated on the public lands in order to encourage large, stable investments. Similar marketing policies are needed for the woodfuel industry. There may be significant political obstacles to such a radical change. Forest industries should be given an opportunity to help formulate these policies. Public land managers should also participate.

In order to publicize these perspectives the North Central Forest Experiment Station in cooperation with the Fiber Fuels Institute, the Natural Resources Research Institute, and the University of Minnesota scheduled a conference in early November of 1985 for land managers, forest industry, existing and potential fuelwood users, fuelwood producers and processors, equipment manufacturers, and environmental groups. The major objective was to provide an opportunity for each interest group to establish their own action agendas.

METHODOLOGY

Simulating Timber Supply - Wood Energy Development Now is Crucial to Future Supplies--A simulation model was developed and tested that can be applied to large timber harvest scheduling problems which are beyond the practical limits of general linear programming techniques.

These new techniques were applied to NE Minnesota. A large wood energy increase could be achieved without significant negative impacts on the supply costs of other forest products. Increased wood energy could actually help reduce future supply costs.

Developing Growth and Yield Data for the Extremely Varied Forest Types and Stand Conditions in the Region--Inadequate growth and yield information has been developed for mixed stand conditions. Contemporary individual tree based models provide short-term projections but have not been thoroughly tested for the long term. A study in cooperation with the University of Minnesota developed an automated growth and yield projection system based on existing Forest Survey data and seems better suited for long-term timber supply analyses. System characteristics are (a) rapid access to growth and yield data; (b) sensitivity to a range of forest types, stand conditions and treatments; (c) sensitivity to harvest method and utilization levels; (d) accurate over at least one rotation.

Assessing Harvest and Transport Costs--Harvest and transport costs are probably the two most important factors determining whether wood is used, regardless of the considerable expense already incurred to grow and protect it. Our scheduling model required these costs in order to estimate wood supply. A study in cooperation with the University of Minnesota determined the effect of stand diameter and basal area on the cost of several systems recovering both roundwood and chipped material.

Analyzing Wood Energy Systems Engineering and Economics--The technology regarding woodfuel equipment requirements, operating costs, and financial returns is rapidly changing. A study in cooperation with the University of Minnesota has (1) identified appropriate wood handling, storage, pollution control, and combustion equipment for a range of industrial/commercial energy consumers; (2) developed a range of cost projections for replacing existing process and space heating equipment with wood systems for each class of wood energy user; (3) determined the effect of woodfuel prices on the economics of each system; (4) developed detailed cost and engineering data for installations representative of selected classes of energy users. These installations were selected to represent a wide variety of potential users in the study area. A manual for prospective wood energy users is being prepared.

Estimating Long- and Short-Term Wood Energy Demand--In spite of the widespread availability of inexpensive woodfuels in northeastern Minnesota, only the forest industry and residential sectors use wood for fuel. For most other sectors, wood energy demand has experienced only minor changes during rapidly rising energy prices. A study in cooperation with the University of Minnesota, Duluth, identified current wood raw material availability, energy demand, current supply, and projected future demand levels for all sectors.

Using an Input-Output Model to Estimate the Economic Impact of Wood Energy--An updated input-output model was developed for northeastern Minnesota in cooperation with the University of Minnesota, Duluth. It had already been used to evaluate the impacts of changing pulpwood markets and the new waferboard industry in northern Minnesota. It was now used to determine the impacts of current and future substitutions of wood for fossil fuels.

Identifying and Ranking Policy Options to Encourage Wood Energy--Among the many factors that impeded residue use are a variety of often conflicting

policies and regulations. For example, pricing policies that discourage removal of forest residues, public-private timber supply agreements of extremely short duration, and forest regulation policies usually founded on biological rather than economic and social principles. A study in cooperation with the University of Minnesota (1) identified public and private policies that enhance or constrain the use of woodfuels, (2) suggested alternative policies and programs to encourage the use of wood energy, and (3) assessed the relative characteristics of current and prospective programs that could be used.

Opportunities for Increasing the Use of Wood Energy from the Chequamegon National Forest--This research estimated the potential biological supply of forest residues on the Chequamegon National Forest under traditional management techniques. The potential is large, and it will probably increase significantly in the next several decades. Specific attention was given to the different forms of forest residue. Forms ranged from tops and limbs left from intermediate thinning operations to surplus growing stock. Separate residue estimates were developed for ten different cover-type classes. A "promotional brochure" is being prepared. Funding for this study was provided by the Department of Energy.

TECHNOLOGY TRANSFER

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Bradley, Dennis P. "Prospects for Forest Fuels in Northeastern Minnesota: A Progress Report." Fiber Fuels Institute Technical Conference, Superior, Wisconsin, August 10, 1984.

Hoganson, Howard M. "Long Term Availability of the Forest Resource for Energy Use." Fiber Fuels Institute Technical Conference, Superior, Wisconsin, August 10, 1984.

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Computer Models Developed

Input-output tables for Northeastern Minnesota - A basic set of input-output tables for the region and a revised set with the presence of wood energy as a substitute for

imports. The revised set of tables contains new industrial multipliers on the basis of this new industry.

A microcomputer spread sheet model was developed to show the impact of prices, combustion efficiency, woodfuel preference, and conversion rates on wood energy requirements.

Conferences (planned)

In November 1985, a regional wood energy conference was held in Duluth, MN hosted by the Forest Service, USDA, NCFES, Fiber Fuels Institute, and University of Minnesota. The purpose was to summarize the recent research effort focussed on NE Minnesota and to use this evidence to identify regional opportunities in the Lake States.

V. THE NORTHWESTERN MONTANA ASSESSMENT

BACKGROUND

Wood fiber currently is an important source of energy not only in northwestern Montana but throughout the Inland Empire region, which extends into northern Idaho and northeastern Washington. In the past twenty years and especially in the last ten years, large scale use of wood for energy has developed.

Although timber utilization practices have improved significantly in recent years, large volumes of wood residues remain unused. An increase in wood residue utilization depends upon such factors as availability, accessibility, outlook for continued supply, and cost of recovery.

A recent General Accounting Office report identified one of the barriers to improved utilization as insufficient assessment of residue utilization opportunities on a localized, site-specific basis. More comprehensive information for specific areas is considered essential for industrial planning and capital investment, for predicting future wood supply, and conducting economic feasibility analysis.

To attempt to provide this comprehensive information essential to improved residue utilization, a cooperative project was undertaken involving the Intermountain Forest and Range Experiment Station of the U.S. Forest Service and the Bureau of Business and Economic Research at the University of Montana. The project was funded by the U.S. Department of Energy.

The study area chosen for this project was the area comprising the timber supply zone for primary wood products manufacturers in Libby, Montana. The area surrounding Libby, Montana was chosen for the following reasons:

1. It is centrally located in one of the largest timber-producing regions in the Inland Northwest.

2. It is a major wood products producing center.

3. Historic harvest levels and species composition indicate large volumes of forest residue should be available in the area.

4. There has been considerable local interest in residue utilization for power generation.

5. Most of the timber harvest activity occurs on National Forest lands or industrial forest lands, making resource data readily available.

The principal goal of this project was to provide the detailed information necessary to assess the feasibility of increased wood fiber residue utilization. The emphasis was on the use of wood residue for electrical generation in northwestern Montana. An additional goal of the project was to develop methodology which could be applied in other geographic areas to analyze residue availability. The objectives of the study were to:

1. Develop detailed estimates of present and future wood residue volumes, locations, characteristics, and availabilities in the Libby area.

2. Estimate the costs of recovering residue of various types.

3. Identify the potential for and needs of improved technology for residue recovery.

4. Evaluate the financial feasibility of supplying a power generating facility with wood fiber residue.

5. Identify additional barriers to residue utilization and/or benefits from increased residue utilization.

This summary provides the highlights of the study and focuses on estimates of residue availability and cost and the financial analysis of wood energy facilities.

FUELWOOD SUPPLIES

Wood fiber residue in the Libby area has two major components: mill residue and forest residue. Mill residue is wood fiber residue generated from processing logs into lumber, plywood and other wood products. Forest residue is that component of the available timber resource not currently being utilized. It includes slash from logging operations and road right-of-way projects, as well as dead and cull green material on sites not scheduled for logging, and small stems from timber stand improvement projects.

Unutilized mill residue generally is a much cheaper source of wood fiber than forest residue. However, much of the mill residue generated annually in the region is committed. Therefore, a new power generating facility in the area may have to compete directly with existing users for this source of wood fiber. Because mill residue is inexpensive when available, it will be discussed in detail.

The most promising source of forest residue available to supply a large volume user is produced during conventional sawtimber harvesting operations. This component, referred to as logging residue, is the cheapest and most accessible type of forest residue resource and was focused on specifically in this project. Other components of forest residue were assessed in less detail.

Mill Residue--All plants processing timber into primary wood products generate mill residue. However, over 95 percent of the mill residue generated in the Inland Empire comes from sawmills and plywood plants. This analysis deals with mill residue from only these operations.

The three types of mill residue generated at sawmills and plywood plants are: 1) coarse or chippable residue consisting of slabs, edgings, and trim from lumber manufacturing, log ends from sawmills and plywood plants, pieces of veneer not suitable for plywood manufacture, and peeler cores from plywood plants not sawn into lumber; 2) fine residue consisting of planer shavings and sawdust from sawmills and sander dust from plywood plants; and 3) bark, from sawmills and plywood plants.

The estimates of annual supply of residue were developed by applying mill residue volume factors to projected lumber and plywood production in the region for a year of normal or average demand for lumber and wood products.

Annual demand estimates were based on the volume of wood the residue utilizing facilities require to operate at capacity, except for the volume of residue needed to dry lumber and veneer, which was based on assumed production.

Coarse residue is utilized primarily as a raw material by the pulp and paper industry. Fine residue is used as a raw material for the pulp and board industry and for fuel, while bark residue is used almost exclusively for fuel. There is a large demand for coarse residue within the Inland Empire. Accompanying the high demand for coarse residue is its higher price, \$30-\$80 per cunit FOB producer's mill, versus under \$10 for fine residue and bark. 2/

A new user, such as a power generating facility using fine residue and bark, would certainly try not to compete for coarse residue and concentrate on the lower cost residue components.

2/ A cunit is 100 cubic feet of solid wood, and approximately 2,500 pounds oven-dry weight.

The Inland Empire's estimated annual supply of mill residue should exceed regional demand in a normal year by nearly 460 thousand cunits. Sawmills and plywood plants will generate just over 3.95 million cunits in a normal year. Estimated requirements from users within the region are 3.49 million cunits.

Virtually all of the excess coarse residue, 270 thousand cunits, is utilized by manufacturers out of the region (Keegan and Jackson, 1984). Projected supplies of fine residue and bark should exceed demand by 190 thousand cunits for a year of normal lumber and plywood production. Because bark and fine residue can be substituted for fuel, individual estimates of excess volumes were not made in the Inland Empire region.

Between 100 and 120 thousand cunits of unused fine residue and bark should be at mills in Lincoln County, Montana, and adjacent counties in north Idaho and northwestern Montana. Canadian mills nearest Libby could supply an additional 30 to 50 thousand cunits.

The entire volume would not necessarily be readily available. For example, some of the excess would be at small mills. The high fixed cost associated with chipping, hogging, and storing residue may make recovery from some of these mills uneconomical.

Users in northwestern Montana should, however, be able to contract annually for volumes of unutilized fine mill residue and bark of slightly more than 100 thousand cunits, given lumber production levels at or above normal levels. This material, delivered to a user in Lincoln County, would certainly cost less than recovering forest residue.

Delivered costs for fine residue and bark should range between $10 and $30 per cunit. Cost to a mill utilizing its own excess residue would be lower, an estimated $5 per cunit. As will be discussed later, competition could make the price of bark and fine mill residue considerably higher in the future. In addition, if a user required the entire 100 thousand plus cunits annually, it would probably be necessary to either sharply curtail operations during periods of lower than normal lumber production or rely heavily on forest residue.

Forest Residue--Timberlands in the northern Rocky Mountains hold large quantities of wood fiber which are neither sawtimber nor desirable growing stock.

Much of it is not utilized and would fall into the general category of forest residue. For purposes of this report, forest residue was defined as:

1. Logging residue which consists of dead and cull green material including crowns and unmerchantable bole tips currently left on logging sites, and cull portions of the boles of sawtimber trees.

2. Material cut and left on site in timber stand improvement practices such as thinnings or stand conversion operations.

3. Material remaining from past years' logging operations.

4. Dead, small and cull green material on sites not scheduled for commercial harvesting operations or timber stand improvement.

The potential of these sources to supply major users of wood fiber in the Libby, Montana area was examined. Specifically, the objectives were to estimate: 1) the volumes of the various components of forest residue available annually for the period 1986 to 1995, within a 100-mile haul of Libby, Montana, and 2) the cost of recovering that material. The forest residue supply schedule for the Libby, Montana area is shown in table 3. It is categorized by logging residue and other components of forest residue. Only logging residue appears

Table 3

Forest Residue Supply Schedule Available
Annually to an Energy Facility
Libby, Montana
1986-1995

Source	(1000 Cunits)	Estimated Cost (1984 Dollars)
Logging residue volume through whole tree recovery[1]	120-200	\$25-\$65/cunit Average \$45/cunit
Cull logs and trees from tractor sites	41	\$65/cunit
Cull logs and trees from cable sites	17	Over \$80/cunit
Other forest residue components		
Stand conversion residue		
Slopes to 20 percent	Under 10	Over \$65/cunit
Slopes 20-40 percent	Under 20	Over \$80/cunit
Backlog slash	Minimal	Over \$80/cunit
Selection or salvage logging Cull material	Large Volumes	Over \$80/cunit

Source: University of Montana, Bureau of Business and Economic Research, Libby, Montana Logging Residue Inventory (Missoula, Montana, 1984).

1/ The lower volume estimate in this schedule represents wood fiber available by in-woods processing of whole sawtimber trees. The upper volume figure represents estimated volumes available if mill site processing is undertaken. The costs of wood fiber available through the two approaches did not differ greatly. Also included in the estimate are 38 thousand cunits representing cull portions of the boles of sawtimber trees currently bucked-out and left on logging sites.

potentially able to supply large volumes of additional wood fiber in the Libby, Montana area at a reasonable cost.

Probably the best logging residue components suitable for fuel in an energy facility are the tops and crowns of sawtimber trees and cull portions of boles of sawtimber trees recovered in whole tree logging operations. An estimated 120-200 thousand cunits would be available annually through whole tree logging in the Libby, Montana area for an estimated cost of $25 to $65 per cunit (delivered and chipped), with an estimated average cost of $45 per cunit in 1984 dollars.

Crowns and unmerchantable bole tips of sawtimber trees are especially advantageous to energy users. First of all, they are potentially cheaper than the other components of forest residue. Second, there would be little competition from producers of products such as pulp and paper or waferboard because these users generally require wood fiber pieces large enough to flake or chip and have a low tolerance for bark.

However, the recoverable volumes and cost of crowns and unmerchantable bole tips is uncertain. Much of the recovery data used in this analysis is from case studies done in other regions in North America. Nevertheless, it is the only source of forest residue in the Libby area that would have the potential to supply a relatively large user at a relatively low cost.

As the material recoverable in whole tree operations is exhausted, the next most promising type of forest residue should be cull logs that could be recovered during sawtimber harvest operations on tractor ground. The volumes of this material in the area appear limited, with only about 41 thousand cunits of additional material available from all tractor ground in the supply zone at an estimated cost of $65 per cunit.3/

Components of forest residue other than logging residue cost much more than most logging residue. The next least expensive source of forest residue appears to be residual material from the conversion of stagnant lodgepole pine stands in the area. This material, however, is unable to supply large volume users except at a high cost. Given a ten to fifteen year liquidation period for the stagnant stands, an estimated 10 thousand cunits would be available annually from slopes under 20 percent. It would have an estimated cost of more than $65 per cunit. The 20 thousand cunits available annually from slopes from 20 to 40 percent would have an estimated delivered and chipped cost of more than $80 per cunit.

Some wood residue is available in the form of untreated or improperly treated slash from logging operations completed in the past. In the mid-1970s untreated slash in the Northern Region represented a very large volume of material. Regional office personnel feel that since the mid-1970s slash treatment has kept pace with harvesting operations. Large volumes of untreated slash for more recent years would, therefore, not be available. The inventory of logged-over lands completed as part of this project also indicates greatly improved slash disposal and treatment.

3/ These estimates include only logging residue in pieces larger than 4 cubic feet in size. Much greater volumes of smaller pieces would be available but at much higher costs.

Volumes of backlog slash that were available would be generally expensive to recover because relogging an area for residue is generally much more expensive than recovering it at the time of the initial logging operation. Backlog slash areas could not, therefore, be expected to contribute wood fiber to a potential large volume user.

There are large volumes of dead and cull material on sites not scheduled for logging or stand treatment operations. Some of it is currently recovered in salvage operations, especially for use as house logs or home firewood. Selective logging of this residue material would have estimated costs of over $80 per cunit to a large volume user.

Mountain Pine Beetle Epidemic--An infestation of mountain pine beetle in the supply area has reached epidemic proportions. It is anticipated that all lodgepole pine (LPP) stands over eighty years old and 6 inches in diameter on the Kootenai National Forest will be infected by the mountain pine beetle within the next ten years. This represents a volume of just under 3 billion board feet.

The Kootenai National Forest has undertaken a large salvage program aimed at recovering the impacted LPP for lumber production. Because of constraints imposed by the ability of the wood products industry in the area to absorb LPP and constraints imposed by accessibility and other resources, harvest levels will be much lower than anticipated losses.

Given present recovery rates, only about one-third of the 3 billion board feet of dead LPP will have been recovered by 1995. Since at that time much of the LPP will have been dead for more than ten years, its potential for lumber recovery will be greatly reduced. Beetle killed LPP could then become a major source of wood fiber for fuel in the period after 1995.

IMPACTS OF INCREASED FUELWOOD USE

Wood is only one of the materials necessary to produce outputs of energy or wood products. The long-run value of wood varies for each user depending on the value of the product produced and the rate of return required, as well as on other production costs and the availability of wood versus potential substitutes.

Because of the variability in value of wood to a specific plant, ranges were developed to reflect what energy users and potential competitors could pay over the long term for wood fiber (table 4). The estimates are not precise figures of the value of wood to various users, but only an indication of whether or not plants or facilities might be expected to purchase wood in competition with other users in the Inland Northwest.

The assumption was made that wood fiber in quality up to and including material suitable for stud logs and house logs might be used competitively by fuel or fiber facilities.

The uses of wood to manufacture a product generally have a higher value use range than the energy uses. A number of energy uses for wood, however, have value use ranges that overlap those of the product uses.

The uses of wood as a substitute for coal or to generate electricity have value ranges well below those for most manufacturing uses. The exceptions would be low-value manufacturing uses such as particleboard production.

It appears, however, that wood could substitute for fuel oil and natural gas in industrial boilers, and be competitive with a number of product uses. The value use range for wood in place of fuel oil or natural gas is large, due primarily to variability in capital costs of wood boiler systems. At the lower end of the capital cost scale, using wood as a fuel appears competitive with many product uses.

Table 4

Estimated Value Use of Wood Fiber
Energy and Selected Products
Inland Empire Region
(1984 Dollars)

Use	Mill Delivered Value per Cunit
Electrical Generation	\$ 0-\$ 25
Industrial Fuel to Replace	
Coal	\$ 25-\$ 35
Natural Gas	\$ 0-\$ 65
Fuel Oil	\$ 0-\$ 70
Raw Material to Produce	
Reconstituted Boards	
Particleboard	\$ 15-\$ 40
Fiberboard	\$ 30-\$ 80
Waferboard	\$ 40-\$ 80
Pulp and Paper	\$ 40-\$ 80
Solid Products	
Post, Rails, Poles	\$ 50-\$ 80
Studs	\$ 60-\$ 90
House Logs	\$ 100+

Much of the variation in value use for products relates to market conditions. Wood as a substitute for natural gas or fuel oil could compete with the particleboard and fiberboard industries under both good and bad wood products market conditions. During periods of high demand for pulpwood or solid wood products, energy users of wood might have a difficult time competing.

The Inland Empire has seen virtually no large-scale competition between industrial fuelwood users and manufacturers using wood as a raw material or among fuel users or manufacturers. Competition between wood energy users and manufacturers has been limited, primarily because industrial fuelwood users used material that was either not suitable for product uses or was available in quantities much greater than needed. This situation could easily change in the future.

Almost all of the industrial fuelwood needs in the Inland Empire have been met by utilizing the wood fiber residue from the manufacture of lumber and plywood (mill residue). The mill residue components generally used for fuel are bark and fine residue (composed of planer shavings and sawdust). No major manufacturers in the region currently utilize bark as a raw material to produce a product. Planer shavings and sawdust are used as a raw material by particleboard and fiberboard plants and sawdust by pulp and paper mills. However, during years of average and above-average lumber production, supplies of these have exceeded fuel and raw material needs. Because of this surplus, there has been little direct competition between energy users and product users. Low prices for bark and fine residue (currently priced at under $10 per cunit FOB the producer's mill and averaging under $25 per cunit delivered to the user) reflect this lack of competition.

Excess mill residue still exists in the region, at least in years of average or above lumber production. A new user, especially in northwestern Montana and north Idaho, might still be able to secure moderate volumes (100 thousand cunits of fine residue and bark) for prices well below those indicated by the value uses in table 4. This situation, however, may exist only in the near term.

The projected excess supply of mill residue for years of average lumber production is small in relation to total supply and demand, with the estimated unutilized volume of fine residue and bark representing less than 10 percent of the total supply (table 3). Therefore, even modest increases in average annual demand for residue (or small decreases in the size of the lumber and plywood industry) would over the long term lead to greater direct competition among users of wood fiber residue and much higher prices for bark and fine residue available at sawmills and plywood plants.

A prospective user of mill residue must be aware that lumber production varies considerably from year to year, due to volatile lumber markets. Five of the ten years between 1974 and 1983 were years of below-average lumber and plywood production. Given current demand for mill residue, short-falls of supply would occur if lumber production dropped to the levels experienced in any of those five years.

The coming decade should not include a recession in wood products as severe as during 1980-1982 and shortages are not necessarily projected for five of the next ten years, but users should remember that downturns in the lumber markets can occur at any time. Users may be forced in lean years to pay much more for wood fiber, either because competition for mill residue has driven prices up or because they are forced to recover forest residue.

Both in the near and distant future, new large-volume users of wood for energy should be prepared to pay more

for wood than was paid in the past for fine mill residue and bark -- unless they have firm long-term contracts for mill residue.

BARRIERS TO WOOD ENERGY DEVELOPMENT

The major focus of this project was on the volumes of wood fiber residue available at various prices and the financial feasibility of using wood fiber residue in energy facilities. Based on this analysis, the authors felt that utilization of wood fiber residue for energy in Montana is constrained primarily by the cost of recovery and/or the revenue from the sale of energy (or the dollars saved substituting wood for other fuels). Additional barriers to residue utilization in the area include a complex permitting and siting process, shorter contract periods for timber than for fossil fuels, and various environmental concerns of the landowners and managers. A number of these are discussed below.

Permitting--The major noneconomic barrier to the increased utilization of wood residue for energy is a complex and poorly defined permitting process. In response to this barrier, the Montana Department of Natural Resources is developing a handbook to simplify the process of establishing bioenergy facilities in Montana. The Bonneville Power Administration is initiating the development of a similar document covering the entire Northwest.

Contract periods for wood fiber.--The most available component of the forest residue resource -- logging residue -- can be removed efficiently only in conjunction with sawtimber harvest operations. The typical sawtimber sale extends no longer than five years, much shorter than the supply period commonly entered into for coal. These short-term timber sales can be attributed to land management, budgetary, and legislative constraints as well as volatile and uncertain markets for wood products. Given the poor economic outlook for wood energy, promoting increased utilization of wood for energy would not in itself be a compelling argument for extending the length of timber sales.

Regardless of short-term timber sales, it is possible to obtain longer-term assurances of forest residue. The large mills in the Libby, Montana area, for example, have been operating for up to fifty years on the same site. Large investments are currently being made in lumber processing facilities, meaning a major forest products industry will exist in the area long into the future. An energy facility could certainly enter into long-term contracts for logging residue with both mills and loggers that purchase timber. In addition, some components of forest residue such as stand conversion residue, for which there is no market, would be available on longer-term contracts of up to ten years.

Environmental and management concerns.--The environmental and management consequences of intensive utilization influence many factors, from effects on microbiological functions to aesthetic quality. Some effects, such as fuels reduction, elimination of unslightly residue concentrations, and elimination of physical barriers to management activities, are generally desirable. The potential for adverse impacts exists when the quantity and type of residue material remaining on the site will no longer satisfy the immediate and long-term needs of the ecosystem.

Physically, residues provide ground cover that moderates temperature fluctuations, conserves soil moisture by reducing evaporation, and creates microsites favorable to seed germination. Mechanically, residues provide shade and wind barriers for sensitive seedlings, protect small trees from snow loads, and reduce damage from grazing or browsing animals. Residues remaining on site effectively reduce soil erosion and sedimentation, which can be severe on

logged areas. Residues are also essential elements for wildlife habitat.

Biologically, residues provide the principal energy source for the microbiological processes critical to soil development and plant nutrition. Major processes include nutrient release from organic material through decay processes, fixation of atmospheric nitrogen, and support of ectomycorrhizal fungi.

The potential impacts of intensive residue utilization vary with site conditions, silvicultural prescriptions, and harvesting systems. The highest probability of adverse impact occurs where very intensive levels of utilization are applied in clearcut units, especially in combination with severe physiographic conditions. Harvesting systems designed to remove and process whole trees, as many "small-stem" systems do, are of particular concern because little or no woody residue remains on site.

Given the integral role and function of wood residues in the forest ecosystem, land managers need to assess each situation independently. Decisions regarding utilization level can then be made in a manner that will avoid -- or at least greatly reduce -- the probability of severe adverse environmental impacts.

FEASIBILITY OF REGIONAL IMPLEMENTATION

Using wood for electrical generation--A range of types and sizes of wood-fired systems were analyzed in detail to determine the feasibility of producing electricity using wood residue for fuel. Four specific facilities were evaluated (table 5). These case studies involved two cogeneration facilities and two stand-alone wood-fired plants. Cogeneration is the generation of process steam, process heat, or space conditioning combined with the generation of electrical power. A stand-alone plant produces electrical power only.

The two cogeneration systems evaluated were a 5-megawatt system and a 15-megawatt system. These represent a range of sizes compatible with the industry in northwestern Montana and the Inland Empire region. A 5-megawatt system could be sustained using the low value mill residue (bark, planer shavings, and sawdust) generated by a sawmill producing 40 to 60 MMBF of lumber annually. Coarse residue could also be used to fuel a power facility. Presently, coarse residue is virtually all used by the pulp and paper industry in the region and has a value FOB producing mill in excess of $40 per cunit versus approximately $5 per cunit for bark, planer shavings and sawdust.

The 15-megawatt facility could be supplied by the bark and fine residue generated by a large mill complex processing in excess of 100 MMBF of timber, approximately 70 percent into lumber and 30 percent into plywood.

The two stand-alone facilities were a 15 and 25-megawatt facility.

All costs and variables associated with the two cogeneration alternatives (options 1 & 2) are the incremental costs associated with the production of power. It is assumed that the facility (sawmill, plywood plant, etc.) needs a new process steam system. Therefore, the costs associated with the process steam system are deducted from the total cost of the cogeneration project.

Both net present value and internal rate of return were calculated for the four case studies. This was done for the various levels of capital costs, fuel costs, and revenue rates for electricity. To examine sensitivity to changing levels of capital costs, the base capital costs for the four case studies were increased and decreased by 25 percent. Three levels of wood fiber costs were used in the financial analysis, $5, $20, and $50 per cunit. Finally, the current prevailing fully levelized buyback

Table 5

Summary of Values and Assumptions for the Four Base Case Power Plant Options

Project Type	Option 1 Cogeneration (5 MW)	Option 2 Cogeneration (15 MW)	Option 3 Stand-alone (15 MW)	Option 4 Stand-alone (25 MW)
Project Life	20 yrs	20 yrs	20 yrs	20 yrs
Electrical Capacity (MW)	5.0	15.0	15.0	25.0
Electrical Generation (Million KWH)	40.3	120.9	120.9	201.6
Capital Cost Allocated to Electrical Generation (In Millions of 1984 Dollars)	$ 13.3	$ 30.6	$ 32.1	$ 44.2
Investment Tax Credit (Percent)	10%	10%	10%	10%
Depreciation Method	---------ACCELERATED COST RECOVERY SYSTEM--------			
First Year Operating & Maintenance Costs (In Millions of 1984 Dollars)	$ 0.8	$ 1.6	$ 1.7	$ 2.2
Fuel Consumed to Generate Electricity (Cunits)	24,170	68,030	84,620	141,040
Growth Rate of Operating & Maintenance Costs & Fuel Costs	5%	5%	5%	5%
PURPA Buyback Option	------FULLY LEVELIZED FIXED RATE of 6.27¢/kwh-----			
Tax Rate	46%	46%	46%	46%

Sources: General Electric Company for the Electric Power Research Institute (Palo Alto, California, 1982) and Bureau of Business and Economic Research, University of Montana (Missoula, Montana, 1984).

Notes: All costs and variables associated with the cogeneration facilities (Options 1 & 2) are the incremental costs associated with the production of power. In essence, we have assumed that a facility (sawmill, etc.) is in need of a new process steam system, therefore, all additional costs over and above the process steam facility are attributable to power production.

rate of 6.27¢ per kilowatt hour was used as the base case, and sensitivity to buyback rates up to 9.5¢ per kilowatt hour was analyzed. The internal rate of return selected--14.6 percent--is the return on equity for the 500 largest manufacturing firms in the United states from 1973 to 1983.

Given a discount rate of 14.6 percent, none of the base capital cost cases (capital costs of $1.8 to $2.6 million per megawatt hour) would be attractive investments at current fully levelized electrical buyback rates (6.27¢ per kilowatt hour) even with woodfuel costs of $5 per cunit.

When capital costs are reduced by 25 percent, it is only at the lower wood cost levels ($5 per cunit for the 15-megawatt cogeneration case and $20 for the 25-megawatt stand-alone facility), that the internal rate of return at current fully levelized buyback rates exceeds 14.6 percent.

The cost of wood appears to have a substantial impact on the feasibility of wood-fired generating facilities. Reductions in wood cost greatly increase the net present value and internal rate of return.

At a $50 per cunit wood cost (representing the cost of forest residue) and current buyback rates, none of the cases offered a positive net present value, even at a 10 percent discount rate. Substantial increases in electrical buyback rates would be required before forest residue would be an appropriate fuel to generate electricity, if new equipment were used.

Reducing capital costs to $1 million per megawatt of capacity, possibly through the use of refurbished equipment, can make the generation of electricity from wood considerably more attractive. At wood costs of $5 per cunit, a cogeneration facility would offer an attractive investment with an estimated rate of return of over 25 percent, given current buyback rates. At $20 per cunit at current buyback rates, the facility would still offer a rate of return of over 20 percent. Even at much lower capital costs of $1 million per megawatt, forest residue at $50 per cunit does not appear to be feasible.

Substituting Wood for Fuel Oil or Natural Gas--The cost per BTU of natural gas or fuel oil indicates that in northwestern Montana relatively high costs could be paid for wood as a substitute fuel. Given the systems had equal capital and operating expenses wood systems could absorb a fuel cost in excess of $80 per cunit and compete with natural gas or number 2 fuel oil. Capital costs of wood systems are, however, generally considerably higher than those for natural gas or fuel oil.

The feasibility of developing wood systems depends on whether reductions in fuel costs will offset increased capital and operating costs. A financial analysis of two wood-fired process steam systems was done to examine this relationship. The two systems examined were an 80,000 lb/hour capacity system and a 20,000 lb/hour system, each analyzed at 40 and 80 percent capacity utilization.

Based on these analyses it is apparent that the feasibility of utilizing wood systems in place of natural gas or fuel oil is tremendously variable as is the associated value of wood as a fuel. As long as capital costs in the system are no more than 2.25 to 2.5 times those required for natural gas or oil, as is the case for the larger system examined, the rate of return and net present value of such an investment is favorable. The larger system (80,000 lb./hour capacity) at the high level of capacity utilization would appear feasible even at relatively high wood costs. At wood costs of $50 per cunit, a rate of return of over 25 percent is indicated. When capacity utilization of 40 percent is assumed, the price the facility could pay for wood and still earn an

adequate return is reduced. The rate of return after taxes would be 13 to 15 percent with a $50 wood cost.

As the capital costs of the wood system increase relative to the fossil fuel systems, the financial attractiveness is reduced. The smaller-sized facility examined (20,000 lb./hour) involved capital costs approximately 3.4 times those required for fossil fuels. At 80 percent of capacity utilization and wood costs of $50 per cunit, the system offers an after-tax rate of return of about 15 percent (compared to 25 percent for the larger system). At wood costs of $25 per cunit, the smaller system offers a rate of return exceeding 25 percent--obviously a feasible substitute for natural gas or fuel oil.

At a capacity utilization level of 40 percent, however, the smaller system offers an adequate rate of return only at very low wood costs. At wood costs of $25 per cunit, the after-tax rate of return is approximately 12 percent. The analysis described above indicates that under certain circumstances the wood systems are more financially attractive than fuel oil or natural gas systems and that they can support relatively high wood costs. In fact, if capital costs of the wood systems are only two to two and one-half times those for the two fossil fuels and the facility will operate at a relatively high rate of capacity utilization, wood costs in excess of $50 per cunit could be borne. This should make forest residue a feasible substitute fuel.

There is tremendous variation in capital costs and capacity utilization. The 80,000 pound system evaluated is larger than that required by most steam users in the area. A 20,000 pound system is more in line with the need of many of the potential users. These smaller systems can have much higher relative capital costs for wood systems. Seasonal variation in needs greatly reduces capacity utilization for many users. At significantly higher relative capital costs and low capacity utilization, wood systems may not be feasible even if wood were free.

There are some inconveniences and disadvantages associated with wood use which were not incorporated into the financial analysis. These include the relatively large area needed to store wood fuel, increased fire hazard, slower boiler response times, increased heavy truck traffic, pungent odor from large volumes of chipped or hogged wood, etc. There have been instances in the region where conversions from fuel oil to wood were not undertaken because of one or more of the above listed disadvantages.

Since many facilities already have fuel oil or natural gas systems, the prospect of replacing the existing system further complicates the overall picture. The choice of a wood system and the value of wood as a fuel in place of fuel oil or natural gas must be handled on a case by case basis. The above analysis does establish, however, that wood can be used in place of these two fossil fuels and it can have a relatively high value (up to $70/cunit) as a fuel replacement, especially for larger systems at a high level of capacity utilization.

<u>Future prospects for wood energy development</u>--Only limited additional wood energy development is expected in the region during the next one to five years. This is because electrical buyback rates, which are relatively low, will probably be recalculated and lowered since a surplus of generating capacity persists thoughout the northwest. Also, natural gas and fuel oil prices have declined slightly and may decline even further in the next few years.

In looking ahead five years and beyond the contribution of wood to the region's energy needs should continue to expand. Impetus should be provided primarily through the development of electrical cogeneration projects by

wood products manufacturers in the region. The Northwest Power Planning Council's Regional Plan calls for wood-fueled cogeneration systems to supply as much as 400 megawatts of additional electrical power in the Northwest in the next twenty years.

Primary manufacturing residue has been the only source of raw material for wood-fueled electrical generation in the Inland Empire. Unutilized volumes can support additional expansion of cogeneration capacity. However, a significant expansion based on manufacturing residues would have to be based on a mix of manufacturing and forest residues or it could disrupt the supply of wood fiber to manufacturing plants.

TECHNOLOGY TRANSFER

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